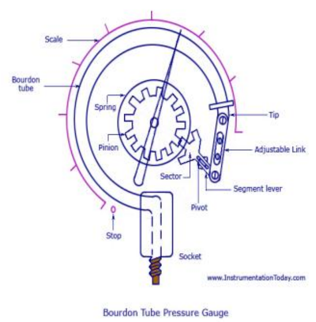
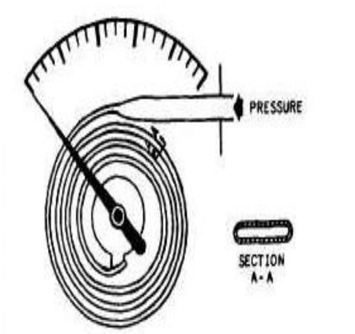
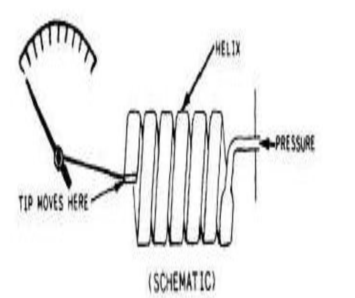
WINTER – 2019 EXAMINATION

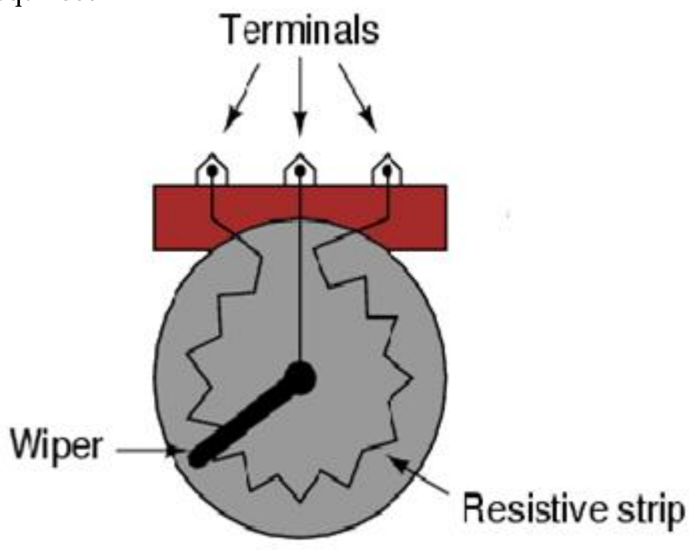
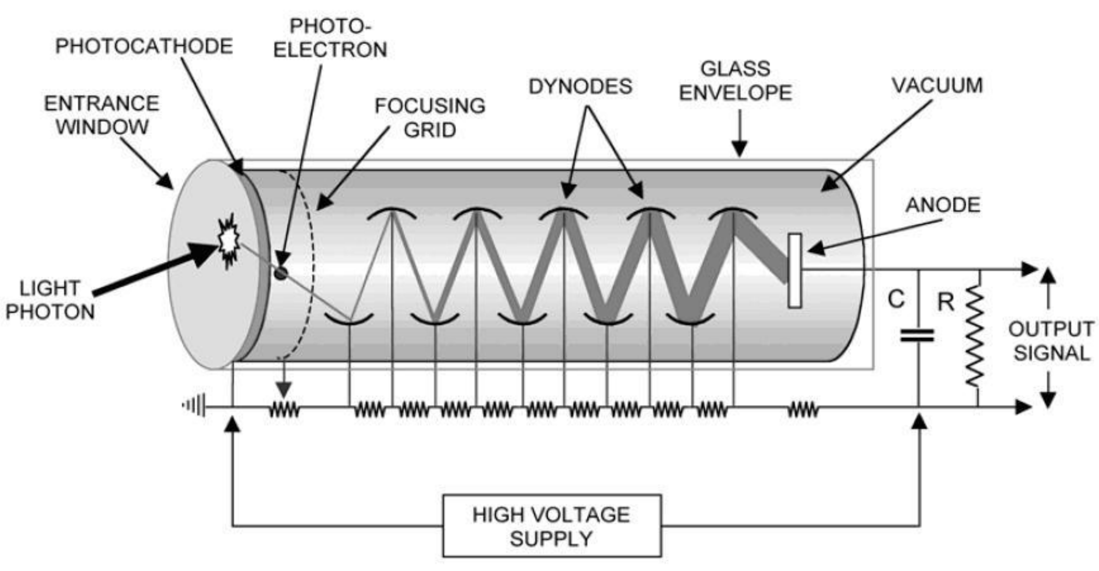
Subject Name: Biosensors **Model Answer** **Subject Code: 22348**

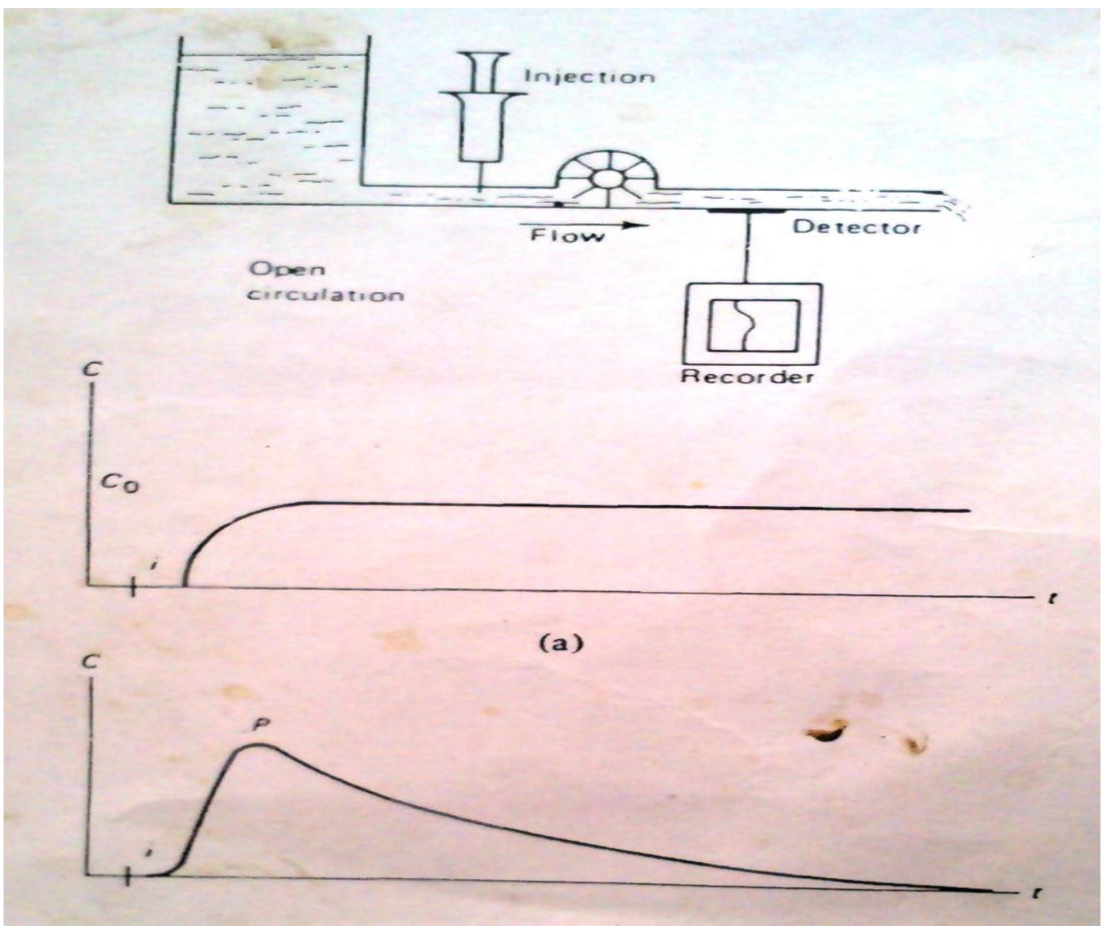
Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance. Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

<table>
<tr><th>Q. No.</th><th>Sub Q. N.</th><th>Answer</th><th>Marking Scheme</th></tr>
<tr><td>1.</td><td></td><td>Attempt any FIVE of the following:</td><td>10 M</td></tr>
<tr><td></td><td>a</td><td>State any two biomedical signals with example.
Ans:
Biomedical signals with example:
1. ECG (Electrocardiography): It is related to heart.
2. EEG (Electroencephalography): It is related to brain.
3. EMG (Electromyography): It is related to muscles.</td><td>02 M</td></tr>
<tr><td></td><td>b</td><td>State any two constraints in design of MIS.
Ans:
Constraints in design of MIS:
1. Inaccessibility of the signal source
2. Variability of Physiological parameters
3. Interference among physiological System
4. Transducer interface problem.</td><td>02 M</td></tr>
<tr><td></td><td>c</td><td>Draw any two types of Bourdon tube with label.
Ans:
<table>
<tr><th>C type Bourdon tube</th><th>Spiral type of Bourdon tube.</th><th>Helical type of Bourdon tube.</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
</table>
Table: Types of Bourdon tube</td><td>02 M</td></tr>
</table>

	d	**State the principle of thermocouple.** **Ans:** **Principle of thermocouple:** The working principle of the thermocouple is based on the seebeck effect. When the heat is applied to junction (hot junction) of two dissimilar metals, an emf is generated which can measured at the other junction (cold junction). The two dissimilar metals form an electric circuit, and current flows as a result of the generated emf. This current will continue to flow as long as $T_1>T_2$. Metal B is describe as negative with respect to a metal A if current flows into it at the cold junction. The emf produces is function of the difference in temperature of hot and cold junctions.	**02 M**
	e	**Describe the working principle of Piezoelectric transducers.** **Ans:** **Working principle of piezoelectric transducers:** Asymmetrical crystalline materials such as: Quartz, Rochelle salt, Barium Titanate and PZT (Lead Zirconate Titanate) produce an EMF when they are placed under stress. This property is used in piezoelectric transducers where a crystal is placed between a solid base and force summing member. When an external force appears on the top the crystal, it produces an EMF across the crystal, which is proportional to the magnitude of the applied pressure. This is self-generating type of transducer.	**02 M**
	f	**State the chemical reaction for PCO_2 electrode.** **Ans:** **Chemical reaction for PCO_2 electrode:** $CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$	**02 M**
	g	**List any two surface electrodes.** **Ans:** **Surface electrodes:** 1. Metal plate electrode 2. Metal disc disposable electrode 3. Suction electrode 4. Floating electrode 5. Flexible electrode	**02 M**
2.		**Attempt any <u>THREE</u> of the following:**	**12 M**
	a	**Give the classification of transducer with example of each.** **Ans:** **Classification of transducer with example:** 1. **Active and passive transducers:** Active transducer e.g. Thermocouple and Passive transducer e.g. RTD. 2. **Analog & digital transducers:** Analog transducer e.g. Thermistors and Digital transducer e.g. Rotary encoder 3. **Primary & secondary transducers:** Primary transducers e.g. bourdon tube and Secondary transducers e.g. LVDT 4. **Transducers and inverse transducers:** Transducers e.g. Thermistor and Inverse transducers e.g. Piezoelectric transducers 5. **Based on Applications:** Temperature: RTD, Thermocouple, Thermistor Pressure: Piezoelectric**,** Displacement: LVDT**,** Force: Strain gauge, load cell.	**04 M**
	b	**Describe with neat sketch construction and working of angular potentiometer.** **Ans:** Angular type potentiometers are used mainly for obtaining adjustable supply	

		voltage to a part of electronic circuits and electrical circuits. The volume controller of a radio transistor is a popular example of angular potentiometer where the rotary knob of the potentiometer controls the supply to the amplifier. This type of potentiometer has two terminal contacts between which a uniform resistance is placed in a semi-circular pattern. The device also has a middle terminal which is connected to the resistance through a sliding contact attached with a rotary knob. By rotating the knob one can move the sliding contact on the semi-circular resistance. The voltage is taken between a resistance end contact and the sliding contact. The potentiometer is also named as the POT in short. POT is also used in substation battery chargers to adjust charging voltage of a battery. There are many more uses of rotary type potentiometer where smooth voltage control is required.  **Fig: Angular potentiometer**	02 M 02 M
	c	**Describe photomultiplier tube with a labelled diagram.** **Ans:**  **Fig: Photomultiplier tube** The entire assembly of the photomultiplier is housed inside a high vacuum tube. The photocathode material can be chosen to optimize the photomultiplier for a particular region of the electromagnetic spectrum. Any metal will exhibit some photoelectric	02 M

		properties - however, the materials most commonly used for photocathodes are alloys of alkali metals, or compound semiconductors, which tend to have a very low work function. Popular materials include S-20 Multialkali (alloy of sodium, potassium, antimony and caesium), and indium gallium phosphide (In Ga As). Photomultiplier tubes operate using photoelectric effect and secondary emission. When light is incident on the photocathode, it emits electrons into the vacuum tube. These electrons are focused towards the electron multipliers (dynodes), which multiply the signal by secondary emission. These multiplied electrons are converted into an output signal by the anode.	**02 M**
	d	**Explain the flow measurement by indicator dilution method with neat diagram.** **Ans:** The indicator or dye dilution methods are the only method of blood flow measurement that really measures the blood flow and not the blood velocity. In principle, any substance can be used as an indicator if it mixes readily with the blood and its concentration in the blood can be easily determined after mixing. The principle of the dilution method is shown in figure. The indicator is injected in to the blood flow continuously, beginning at time t, at a constant infusion rate I (grams/minute). The detector measures the concentration downstream from the injection point. At a certain time after the injection, the indicator begins to appear, the concentration increases, and finally it reaches a constant value, C0 (milligrams per liter). From the measured concentration and the known injection rate. I, the flow can be calculated as, $$F \text{ (litres / minute)} = \frac{I \text{ (milligrams / minute)}}{C_0 \text{ (milligrams / litre)}}$$  **Fig: Indicator dilution method**	**02 M** **02 M**

3. **Attempt any THREE of the following:** **12 M**

a **Differentiate between active transducers and passive transducers.**

Ans:

Active transducers	Passive Transducers
1. Transducer that converts one form of energy directly into another that is it does not require external power supply.	1. The transducer which requires energy to be put it in order to translate changes due to measured. It requires external power supply.
2. It is self-generating transducer	2. It is not self-generating transducer
3. E.g. Photovoltaic cell, thermocouple etc.	3. E.g. LVDT, Strain gauge.
4. These transducers develop their own voltage and current.	4. These transducers are not develops their own voltage and current.

Table: Difference between active transducers and passive transducers

04 M

b **Describe with a neat diagram working of LVDT for displacement measurement.**

Ans:

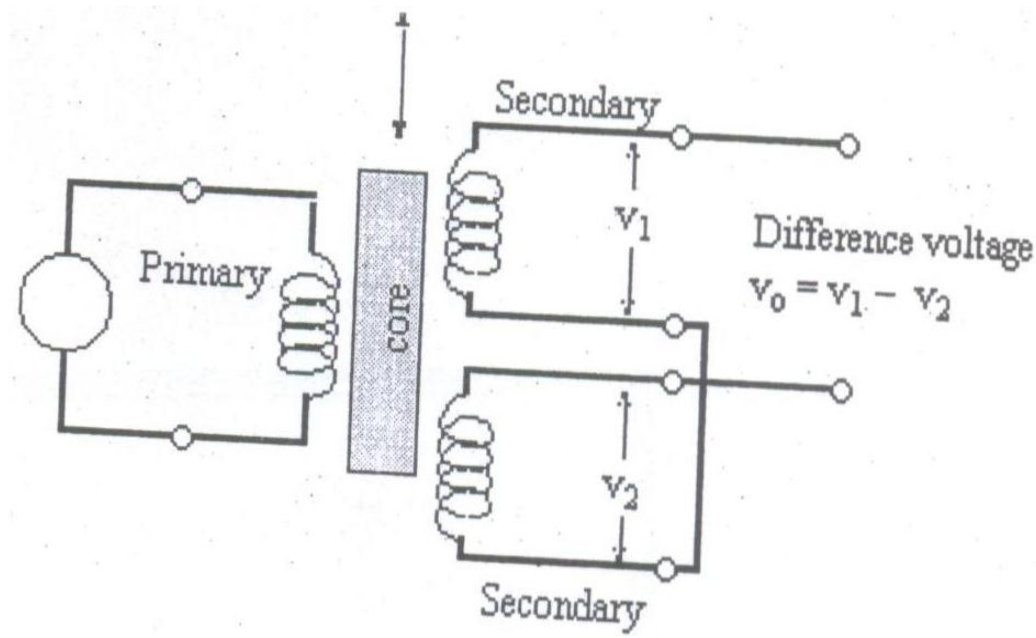


Fig: LVDT for displacement measurement

02 M

LVDT can be used for the measurement of displacement. In this the moving part can be attached to the core of the transformer. When the displacement occurs the core moves upward and downward. As shown in above diagram the potential that will be developed in the secondary windings will be dependent of the position of the core between primary and secondary coil. As a result when core moves some potential is developed in the secondary which will be proportional to the displacement. The exact displacement can be calculated by suitably calibrating the LVDT for unit length and developing potential.

02 M

c **State two types of thermistor and describe it.**

Ans:

Types of thermistor:

1. PTC thermistor
2. NTC thermistor

02 M

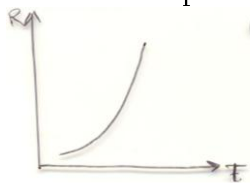
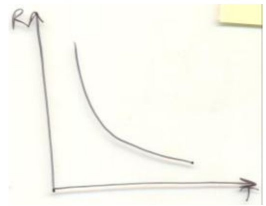
PTC thermistor	NTC thermistor	
resistance versus temperature plot 	resistance versus temperature plot 	
Applications: PTC thermistors were used as timers in the degaussing coil circuit of most CRT displays. For over current in telecommunication applications. For motor starting.	**Applications:** For monitoring the temperature of an incubator. For Food Handling and Processing industry. For Consumer Appliance industry for measuring temperature. Toasters, coffee makers, refrigerators, freezers, hair dryers, etc. all rely on thermistors for proper temperature control. For automotive applications.	**02 M**

Table: PTC and NTC thermistor

d **Draw a neat sketch of pH electrode and describe its working.**

Ans:

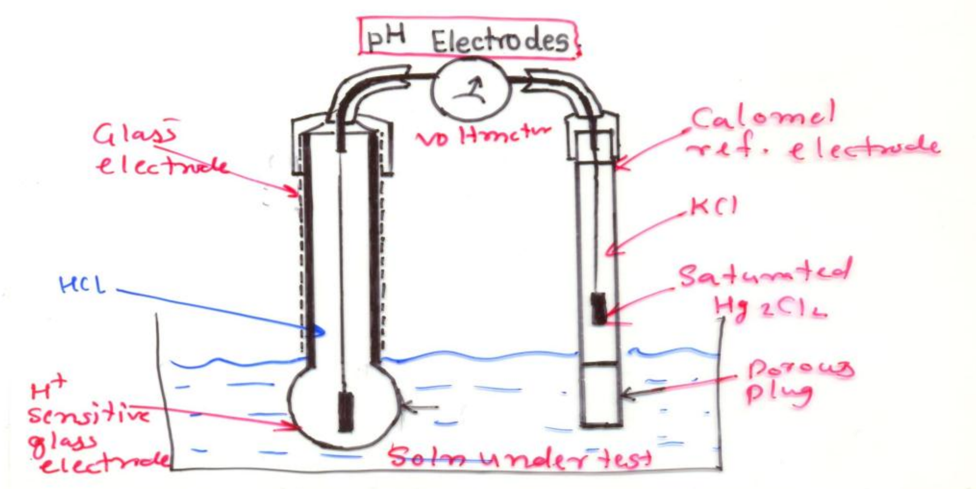


Fig: pH electrode

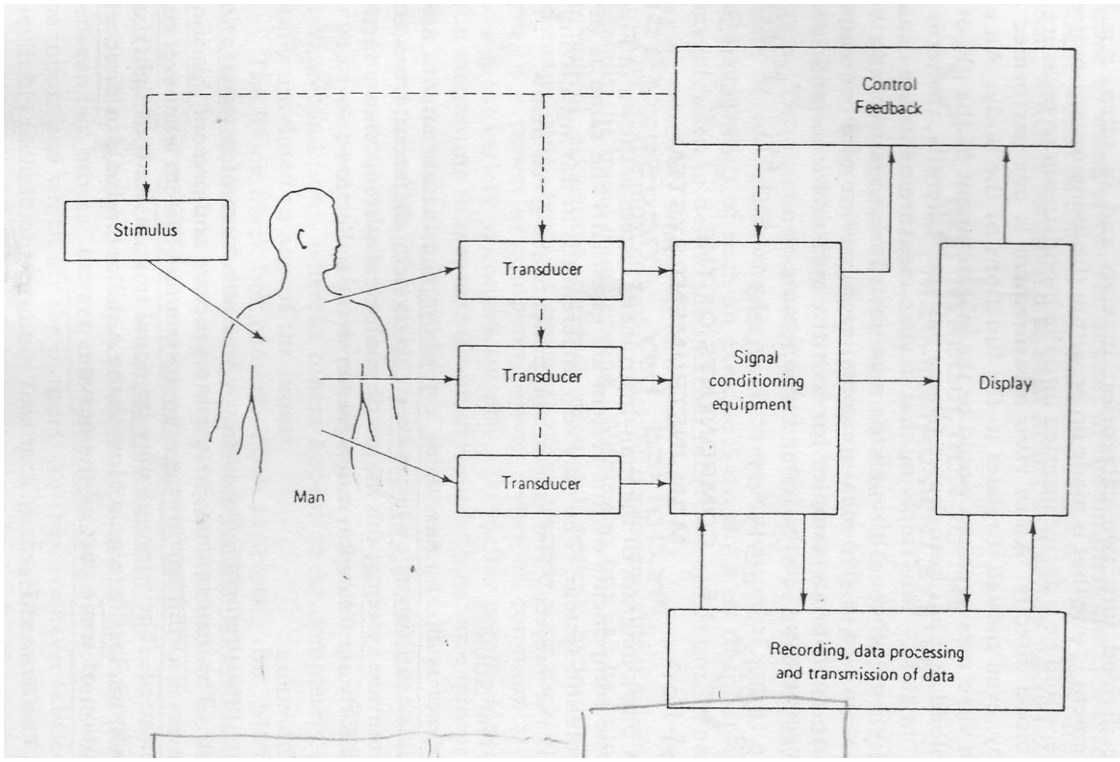
02 M

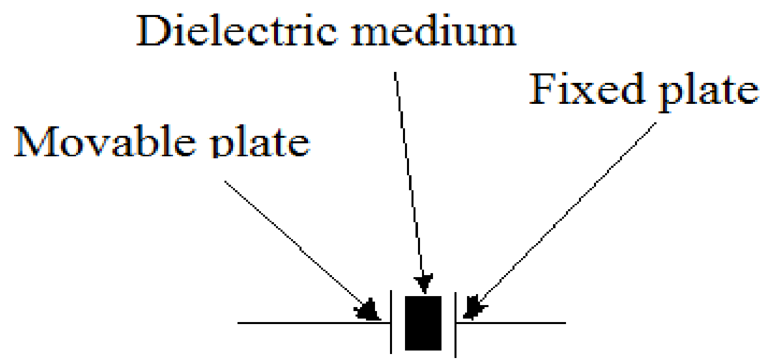
The pH electrode consists of a reference terminal and an active terminal. The reference terminal uses a metal. In this case Ag/AgCl in KCl solution. The salt bridge consisting of fiber wick saturated with KCL is inert to the solution under test. However, it maintains the KCl at a potential of the solution and keep the reference terminal potential essentially the same regardless of the solution under test. The active terminal is similar in concentration to reference electrode but its tip is made up of glass membrane which is sensitive to H^+ ions and thus to pH of the solution. The pH sensitive glass consists of a hydrated gelatinous glass layer. Its membrane potential is proportional to the pH of solution in which it is dipped. Thus the potential difference between two electrodes is a measure of pH. The potential (V) of the glass electrode can be expressed by Nernst equation.

$V = V_o - (2.3036RT/F)\, \Delta pH$

Where, V_o is the standard potential, R is gas constant, T is temperature in Kelvin, F is Faraday's constant, and ΔpH is pH value deviated from 7.

02 M

4.		**Attempt any THREE of the following:**	**12 M**
	a	**Draw neat block diagram of Man Instrumentation System and describe each block.** **Ans:**  **Fig: Block diagram of Man Instrumentation System** **The subject:** The subject is human being on whom the measurements are made. **Stimulus**: The instrument used to generate and present this stimulus to the subject is a vital part of man instrument system when responses are measured. Stimulus may be visual (e. g. flash of light), auditory (e.g. a tone), tactile (e.g. a blow to the Achilles tendon) or direct electrical stimulation of some part of nervous system. **The Transducer:** A device capable of converting one form of energy or signal to another. Here each transducer is used to produce an electrical signal that is analog of the phenomenon. Transducer may measure temperature, pressure, flow or any other variables found in body. **Signal condition equipment:** The part of instrumentation system that amplifies modifies or in any other way changes the electric output of transducer is called signal conditioning Equipment. It also combines or relates the output of two or more transducers output signal is greatly modified with respect to the input. **Display Equipment:** Electric output of signal conditioning equipment must be converted into a form that can be perceived by one of man's senses and can convey information. Obtained by measurement in meaningful way. Input to display device is modified electric signal and its output is some is form of visual, audible or possible tactile information here display equipment may include graphic pen recorder. **Recording Data:** Processing & Transmission equipment - It is often necessary to record the measured information for possible latter use or to transmit it from one location to another on-line digital computer may be part of this system where automatic storage or processing data is required. **Control devices:** A control system is incorporated where it is necessary or desirable to have automatic control of stimulus, transducers or any other part of man instrument system.	**02 M** **02 M**

	b	**Explain the working principle of capacitive transducer with neat diagram. State its two applications.** **Ans:**  **Fig: Capacitive transducer** It consists of a fixed plate and a movable plate which is free to move as the pressure applied changes. According to the change in pressure the movable plate also changes its position, due to which the distance d is changed. With an increase in pressure, the distance d becomes less, due to which the capacitance C is increased (as C α 1/d). With a decrease in pressure, the distance d increases and thus capacitance C is decreased. This change in capacitance can be calibrated to measure the change in pressure. In place of a movable plate a diaphragm may be used, which expands and contacts due to change in pressure. The diaphragm plate acts as a movable plate of a capacitor. A fixed plate is placed near the diaphragm. These plates form a parallel plate capacitor which is connected as one of the arms of the arms of the bridge. Any change in pressure causes a change in distance between the diaphragm and fixed plate, which unbalances the bridge. The voltage output of the bridge corresponds to the pressure applied to the diaphragm plate. The principle of operation of capacitive pressure transducer is based upon the familiar capacitance equation of the parallel plate capacitor. $C = (\varepsilon_0 \varepsilon_r A/d)$ farad Where, C= the capacitance of a capacitor in farad A= area of each plate in m^2 D= distance between the two plates in m $\varepsilon_0 = 8.854*10^{-12}$ farad/m^2 and ε_r = dielectric constant (relative permittivity). **Applications of capacitive transducer:** 1. It is used to measure the pressure, temperature, and displacement, etc. 2. It is used to find the humidity level.	**01 M** **02 M** **01 M**
	c	**Describe the radiation thermometry with neat diagram. Give its applications.** **Ans:** When physical contact with the medium to be measured is not possible or impractical due to very high temperature (above 1400 C), pyrometers are used for temperature measurement. The operation of pyrometer is based on the principal of thermal radiation. Radiation pyrometer measured the radiant heat emitted of reflected by hot object. Thermal radiation is electromagnetic radiation emitted as a result of temperature. In industry where the high temperature of vapors or liquids destroys temperature measuring instruments like thermocouples, thermistors and thermometers, in that case pyrometer is used. Pyrometer work on the principle of thermal radiation, which state that, the energy radiated by a hot body is a function of its temperature. The operation of thermal radiation pyrometer is based on blackbody concept. The total thermal radiation is emitted by blackbody.	**01 M**

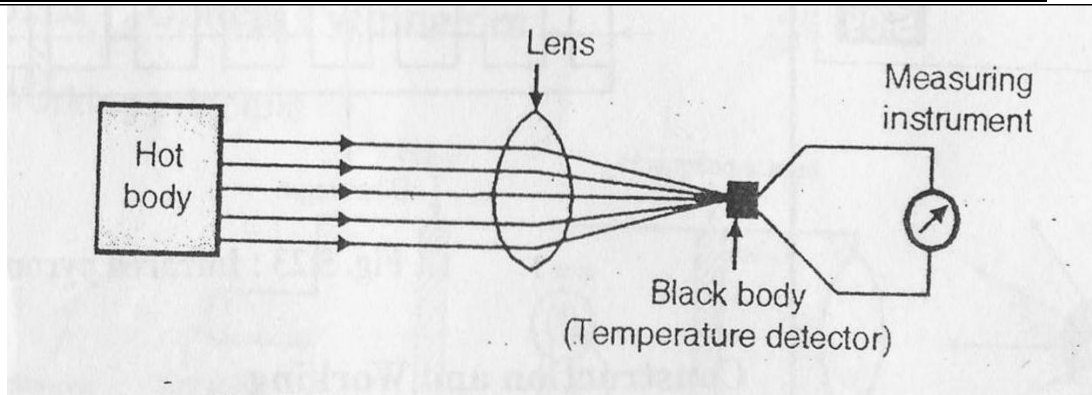


Fig: Radiation thermometry

02 M

Applications of radiation thermometry:

1. Radiation thermometry used to measure internal or core body temperature of the human.
2. It can also be used to find tissue destruction from frost bite and burns and to detect various peripheral blood circulatory disorders.

01 M

d **Draw neat diagram of plethysmography and describe its working.**

Ans:

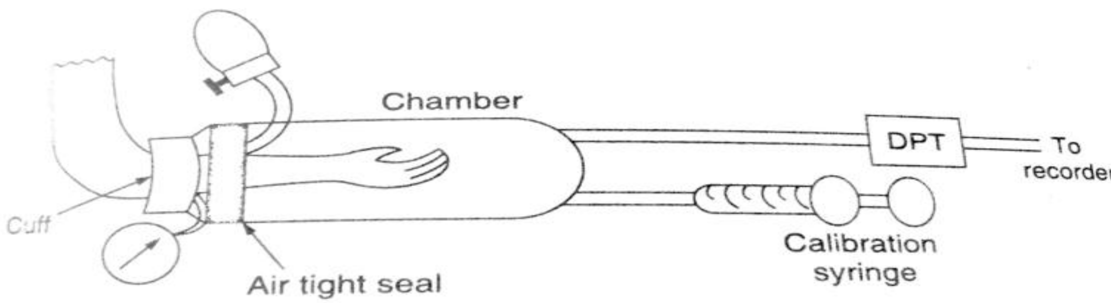


Fig: Plethysmography

02 M

The measurement of blood flow is the measurement of volume changes in any part of the body that results from pulsation of blood occurring with each heart beat. Such measurements are useful in the diagnosis of arterial obstruction as well as for pulse wave velocity measurement. Instruments measuring volume changes or providing outputs that can be related to them are called plethysmographs and the measurement of these volume changes is called as plethysmography. A true plethysmography is one that actually responds to changes in volume, such an instrument consist of rigid cup or chamber placed over the limb in which volume changes are to be measured. The cuff is tightly sealed to the member to be measured so that any changes of volume in the limb reflect as pressure changes inside the chamber. Either fluid or air can be used to fill the chamber. Plethysmography may be designed for constant pressure or constant volume within the chamber. Hence pressure or displacement transducer must be included to respond to pressure changes within the chamber to provide the signal that can be calibrated to represent the volume of the limb. The type of plethysmography can be used in two ways:

02 M

1. If the cuff placed upstream from the deal, it is not inflated; the output signal is simply a sequence of pulsation proportional to the individual volume changes with each heart beat. The plethysmography can be used to measure the total amount of blood flowing into the limb being measured.
2. By inflating the cuff to a pressure just above venous pressure, arterial blood can flow past the cuff, but venous blood cannot leave.

The result is that the limb increases its volume with each heart beat by the volume of the blood entering during that bit.

e **Suggest an electrode for measurement of ECG signal. Describe construction of any one electrode.**

Ans:

Measurement of ECG signal:

1. Limb Electrodes
2. Floating Electrodes
3. Disposable Electrodes.

02 M

Limb Electrodes:

The most common type of electrodes routinely used for recording ECG is rectangular or circular surface electrodes. The material used is German silver, nickel silver or nickel plated steel. They are applied to the surface of the body with electrode jelly. The typical value of the contact impedance of these electrodes, which are of normal size, is nearly 2 to 5 kΩ when measured at 10 Hz. The electrodes are held in position by elastic straps. They are also called limb electrodes as they are most suitable for application on the four limbs of the body. The size of the limb electrodes is usually 3*5 cm and they are generally made of German silver, an alloy of zinc, copper and nickel. They are reusable and last several years.

02 M

Floating Electrodes:

The interface can be stabilized by the use of floating electrodes in which the metal electrode does not make direct contact with the skin. The electrode consists of a light weight metalled screen or plate held away from the subject by a flat washer which is connected to the skin. Floating electrodes can be recharged, i.e. the jelly in the electrodes can be replenished if desired.

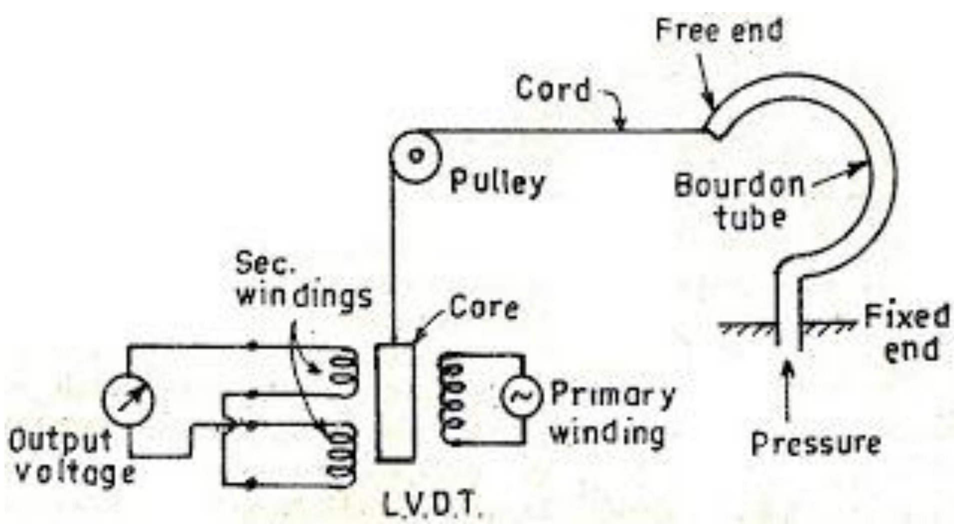
Disposable Electrodes:

The lead wires female connector 'snaps' on, allowing a convenient snap on pull off connection with a 360 rotation providing mechanical and electrical connection. The plastic eyelet or sensor has a diameter of 0.5 to 1.5 cm and is electroplated with silver up to a thickness of 10 µm. The surface of the Ag layer is partially converted to AgCl. The tape is made from one of the adhesive coated occulusive foams made from a plastic, such as polyethylene, or a porous backing, such as non woven cloth. Tapes used for first aid dressings are suitable. The electrode diameters range from 4 to 6 cm.

5. **Attempt any <u>TWO</u> of the following:** **12 M**

a **Describe measurement of pressure using LVDT with neat experimental setup.**

Ans:



03 M

Fig: Measurement of pressure using LVDT

The pressure measurement using bourdon tube and LVDT is shown in above figure. In this the, the bourdon tube act as primary transducer and LVDT which follows the output of bourdon tube act as a secondary transducer. The bourdon tube senses the pressure and converts it into a displacement. The free end of bourdon tube shows this displacement. A cord is used to connect the free end of bourdon tube to the core of LVDT as shown in figure. When the free end shows the displacement, the core of LVDT also moves. This movement of core is proportional to the displacement of free end, which is proportional to the applied pressure. The LVDT gives analogues output which is a conversion of displacement into respective emf. This set up is used for measurement of pressure which is converted into electrical signal by LVDT.

03 M

b **Differentiate between Thermistor and RTD. (any six points)**

Ans:

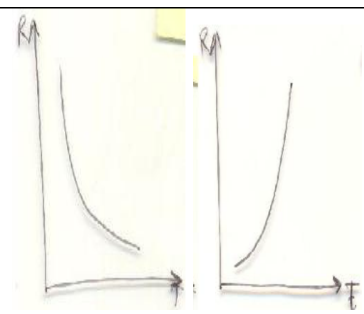
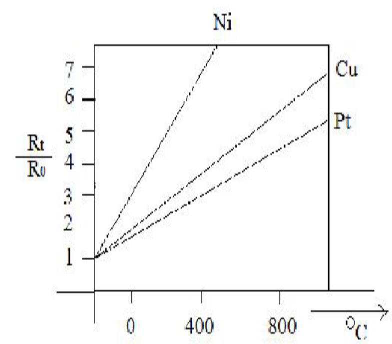
Parameter	Thermistor	RTD
Principle	The resistance of certain metal oxides varies with variation in temperature.	The resistance of certain wire varies with temperature.
Material	Manganese, cobalt, iron oxides etc.	Platinum, tungsten, copper, nickel etc.
Accuracy	More accurate	Less accurate
Temp. range	-150 ^{0}C to 300 ^{0}C	-270 ^{0}C to 2800 ^{0}C
Cost	Low cost	High cost
Characteristics	 Thermistor is the PTC (positive temperature coefficient) and NTC (positive temperature Coefficient).	 RTD is the PTC (positive Temperature coefficient).
Applications	It is used for temperature Measurement in baby incubator.	It is used for measurement of Radiant energy in the industry.

Table: Difference between Thermistor and RTD

06 M

c **Suggest proper transducer for following application:**

i. **Measurement of flow of conducting liquid.**
ii. **Measurement of % of sugar in blood.**

Also explain working principle of each transducer.

Ans:

i. **Measurement of flow of conducting liquid:** Electromagnetic flow meter, Ultrasonic.
ii. **Measurement of % of sugar in blood:** Glucose meter.

02 M

Electromagnetic flow meter, Ultrasonic:

The electromagnetic flow meter measures instantaneous pulsatile flow of blood.

		It operates with any conductive liquid, such as saline or blood. The meter is placed such that the part of body through which the blood is to be determining like limb is subjected to the electric field. The flow meter depends on the movement of blood, which has a conductance similar to that of saline. Faraday's law of induction gives the formula for the induced emf. When blood flows in the vessel with velocity u and passes through the magnetic field B, the induced emf e is measured at the electrodes. **Glucose meter:** The principle behind glucose meter is base on reaction that are analyses by electro chemical sensor on strip there are layer plastic base plate of other layer containing chemical. There is layer containing two electrode silicon or other similar metal there is also layer of immobilize enzyme glucose oxides and other layer containing micro crystalline potatiom terrycynide specifically the reaction of interested is between glucose and glucose oxides the glucose in blood sample react with the glucose oxides to form gluconic acid which then react with terrycynide.	**02 M** **02 M**
6.		**Attempt any <u>TWO</u> of the following:**	**12 M**
	a	**Describe with neat labelled diagram PCO_2 electrode and state its application.** **Ans:**	

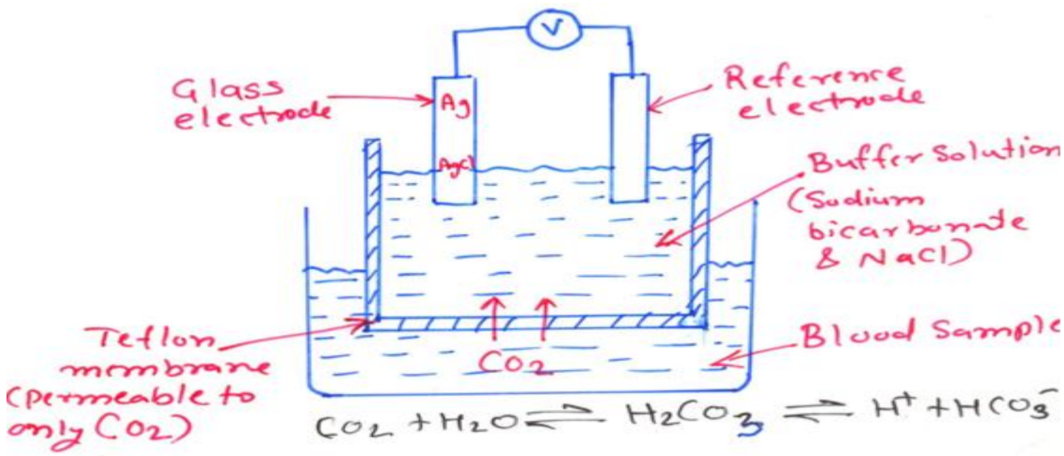


Fig: PCO_2 electrode

		The pH electrode is used as a component of a PCO_2 electrode to measure the partial pressure of CO2 by the arrangement as shown in the figure. Sample chamber with one side made of silicon rubber membrane or Teflon membrane is in contact with another chamber containing sodium bicarbonate solution into which is dipped a pH electrode. Blood or other fluid for which PCO_2 is to be measured enters a sample chamber. It comes in contact with Teflon or Silicon rubber membrane this membrane separates the fluid from sodium solution but it is permeable to CO2 into the solution. CO2 combines with H2O so as to produce free hydrogen ions. **Applications of PCO_2 electrode:** 1. TCM monitoring 2. Pulse Oximetry.	**02 M** (diagram) **02 M** **02 M**
	b	**Describe electrode skin interface with neat diagram and equivalent circuit diagram.** **Ans:** **Electrode-skin interface:** In coupling an electrode to the skin, we generally use a transparent electrolyte gel. Therefore there are two interfaces one is in between electrode and electrolyte (gel) and the other is in between electrolyte and tissue. Ehe: half cell potential of electrode-electrolyte interface. Cd, Rd: Represents impedance of interface (electrode-electrolyte).	**02 M**

Rs: Resistance of electrolyte (Gel). Epidermis is semipermeable to ions, so if there is difference on ionic concentration across this membrane, there is potential difference called Ese. Parallel combination of Ce and Re is represented electric impedance of epidermis. This impedance reduces fro, 200kΩ at 1Hz to 200Ω at 1MHz. Rs Is the pure resistance of dermis and subcutaneous layer.

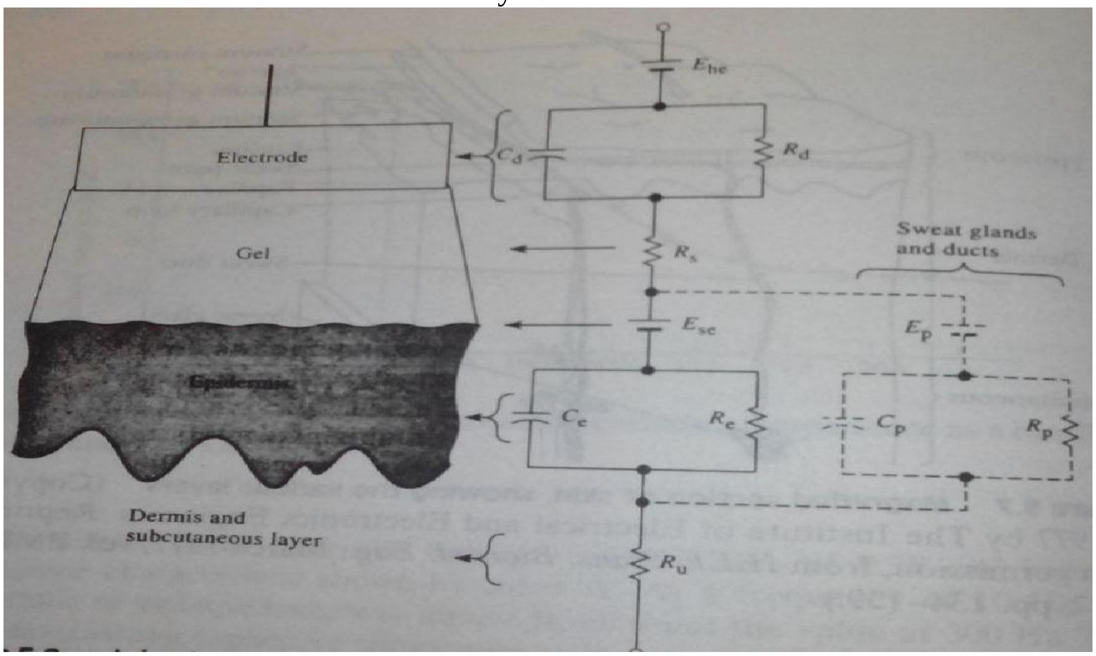


Fig: Electrode skin interface

04 M

c **A platinum RTD has a resistance of 110 Ω at 30 ^{O}C**

i. **Find its resistance at 75 ^{O}C. The resistance temperature coefficient of platinum is 0.00392/ ^{O}C.**

ii. **If the RTD has a resistance of 160 Ω, calculate the temperature.**

Ans:

(a) Using the linear approximation, the resistance at any temperature Θ°C is

$R_t = R_o (1+ \alpha \Delta t)$

Given , Resistance at 75°C is ,

R75 =110 [1 + 0.00392 (75-30)]

R75 =110 [1 + 0.00392 (45)]

R75 =110 [1 + 0.1764]

R75 =110 [1.1764]

R75 = 129.4 Ω

03 M

(b) Suppose t is the unknown temperature

160 = 110 [1+ 0.00392 (t - 30)]

160 = 110 [1+ 0.00392t - 0.1176]

160 = 110 [0.8824 + 0.00392t]

160 = 97.064 + 0.4312t

62.936 = 0.4312t

t=145.95 °c

03 M